GENERAL DYNAMICS | CONVAIR

Report No. 8926-099

Materials - Titanium Alloy - Ti2.5Al-5Sn(A110AT) Stress Corrosion Cracking

B. Faulkenberry, A. Ianucci, F. M. Graber
E. E. Keller

19 May 1959

Published and Distributed
under
Contract AF33(657)-8926

Post Office Box 1950, San Diego 12, California CYpress 6-6611
Material Post Office Box 2071 BRoadway 3-8000 | Accounting Post Office Box 510

Report No. 8926-099
Materials - Titanium Alloy - Ti2.5Al-5Sn(A110AT)

Stress Corrosion Cracking

Abstract

Ti2.5Al-5Sn(A110AT) formed parts which were stress relieved at 1150°F for one hour in heat treating fixtures in such a manner that stresses were generated within parts during heat treatment were found to be cracked just after heat treatment. The cause of cracking was, by a process of elimination, attributed to the presence of sodium chloride deposited on the surface of parts rinsing subsequent to acid etching. The use of "sodium chloride free" rinse water eliminated the stress corrosion cracking.

Reference: Faulkenberry, B., Ianucci, A., Graber, F. M., Keller, E. E., "Effects of Sodium Chloride on Stress Corrosion Cracking of Titanium Alloy During Stress Relieving," General Dynamics Convair Report MP59-053, San Diego, California, 19 May 1959, (Reference attached).

ACCESS NO:

Title: MATERIALS - TITANIUM ALLOY - Ti2.5Al-5Sn(A110AT). STRESS CORROSION CRACKING.

Authors: Faulkenberry, B., Ianucci, A., Graber, F. M., Keller, E. E.
Report: 8926-099 Date: 19 May 1959
Contract: AF33(600)-34814
Contractor: General Dynamics/Convair
ABSTRACT: Ti2.5Al-5Sn(A110AT) formed parts which were stress relieved at 1150°F for one hour in heat treating fixtures in such a manner that stresses were generated within parts during heat treatment were found to be cracked just after heat treatment. The cause of cracking was, by a process of elimination, attributed to the presence of sodium chloride deposited on the surface of parts during rinsing subsequent to acid etching. The use of "sodium chloride free" rinse water eliminated the stress corrosion cracking.

10 pages, 2 tables, 4 figures.

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO

STRUCTURES & MATERIALS LABORATORIES

REPORT MP 59-053

DATE 19 May 1959

MODEL F-106

TITLE

REPORT NO. MP 59-053

EFFECTS OF SODIUM CHLORIDE ON STRESS CORROSION CRACKING OF TITANIUM ALLOY DURING STRESS RELIEVING

MODEL: F-106

CONTRACT NO. AF 33 (600) - 34814

PREPARED BY B. Faulkenberry/A. Iannucci

B. Faulkenberry/A. Iannucci

GROUP Materials & Processes Lab.

CHECKED BY F. M. Graber

F. M. Graber

REFERENCE Mfg. Dev. - P.R. #865

CHECKED BY E. E. Keller

E. E. Keller

APPROVED BY E. F. Strong, Chief Of Structures & Materials Labs.

NO. OF PAGES 10

NO. OF DIAGRAMS 6

W. M. Sutherland, Grp. Engr.

REVISIONS

NO.	DATE	BY	CHANGE	PAGES AFFECTED
1	6/15/59	BHF	Footnote added to Test Specimens & Procedure, #11.	Page 2
8				

FORM 1612A-4

INTRODUCTION:

The Production Line at Plant II has been plagued with excessive stress corrosion cracking of titanium parts during processing per MPS 19.03. This cracking seemed to occur during the stress relieving operation and was thought to be caused by contaminants in the rinse water solution.

OBJECT:

1. To determine if sodium chloride in rinse water causes cracking of A-110 AT titanium alloy during processing per MPS 19.03.

2. To determine at which phase during processing the cracking occurs.

CONCLUSIONS:

1. It was found that rinse water which contained as much as 400 ppm of sodium chloride produced evidence of stress corrosion cracking.

2. It was found that the stress corrosion cracking occurred during the stress relieving operation, Phase 11 of the processing procedure. Therefore, the rinse water used for rinsing in Phase 9 was the solution which determined the amount of sodium chloride left on the titanium surface prior to stress relieving.

RECOMMENDATIONS:

1. It is recommended that a sodium chloride free rinse solution be used for rinsing the titanium parts prior to stress relieving.

2. Additional tests should be continued to obtained a correlation between surface contamination vs. temperature. Also, investigations should be initiated to determine the effect of various ions on the titanium surface in regard to stress corrosion cracking.

TEST SPECIMENS AND PROCEDURE:

Two groups of specimens were made from sheets of 0.032" A-110 AT titanium alloy taken from stock. One group of specimens was made from titanium purchased from the Rem Cru Corporation. The second group was made from titanium purchased from the Titanium Metals Corporation. Specimens measuring 2.5" x 12", with the grain running the length of the specimens, were sheared from their respective sheets and processed as follows:

TEST SPECIMENS AND PROCEDURE: (Cont'd)

1. Immersed in the vapor phase of stabilized trichloroethylene until the flow stopped.

2. Immersed in an Oakite 61-A solution (5-1/2 oz/gal) for 15 minutes, at a temperature of 160°F.

3. Rinsed in agitated distilled water containing varing amounts of sodium chloride. The specimens were rinsed for 3 minutes at a temperature of 150°F.

4. Immersed in a titanium etch solution containing 2% hydrofluoric acid and 30% nitric acid (by weight). The specimens were etched for 5 minutes at room temperature.

5. Same as No. 3

6. Allowed to air dry.

7. Placed in a Tinius Olsen hydraulic testing machine and stretched 3% of their respective lengths.

8. Same as No. 4.

9. Same as No. 3.

10. Dried in a forced air oven for 30 minutes at a temperature of 190°F.

11. Stress relieved at a temperature of 1150°F. for one hour. The specimens were placed under stress as shown in Figure I.*

12. Sand blasted to remove scale formed on specimens during stress relieving.

13. Same as No. 4.

14. Same as No. 3.

15. Allowed to air dry.

Eight sets of specimens were processed as stated above. A different solution of rinse water was used for each set of specimens. The composition of the rinse water solutions for the Rem Cru titanium was as follows:

Set A Distilled water

Set B Distilled water containing 400 ppm of sodium chloride.

* Specimens were 12 inches long and were sprung into the test fixture shown in Figure I. The distance between the two slots was 7 inches and the deflection was 4.12 inches. The outer fiber stress, calculated from equations used for stresses in the elastic region, was above the yield strength so the actual stress could not be determined, but was in the vicinity of the yield strength for the material.

TEST SPECIMENS AND PROCEDURE: (Cont'd)

Set C Distilled water containing 1600 ppm of sodium chloride.

Set D Distilled water containing 3200 ppm of sodium chloride.

The composition of the rinse water solutions for the Titanium Metals Corporation titanium was as follows:

Set E Distilled water.

Set F Distilled water containing 1600 ppm of sodium chloride.

Set G Distilled water containing 3200 ppm of sodium chloride.

Set H Distilled water containing 9600 ppm of sodium chloride.

Following step no. 9, of the processing procedure, the specimens were visually and microscopically checked after each phase of processing to determine the appearance of cracking and other effects.

Discs 1 3/4 inches in diameter were punched from a sheet of 0.032" A11OAT titanium alloy. These discs were hand wiped with MEK, placed in a titanium etch solution for 10 minutes, rinsed with distilled water and allowed to air dry. They were then immersed in solutions of distilled water containing varying amounts of sodium chloride, tagged with Sodium-22, to determine the relative amounts of sodium chloride adsorbed on the metal surfaces. At least two discs were processed for each rinse water solution. By knowing the specific activity of the rinse water solution, the amount of sodium chloride adsorbed on the titanium surface could be determined from the activity of the disc after it had been removed from the solution and dried under a heating lamp.

RESULTS:

Essentially the same effects were observed with the titanium from both the Titanium Metals Corporation and the Rem Cru Corporation. When pure distilled water was used for the rinse solution, all specimens were found to be free of cracks and corrosion pitting as shown in Figure II. Specimens that were rinsed in distilled water containing from 400 to 9600 ppm of sodium chloride were found to have an increasing amount of surface corrosion pitting as the concentration of sodium chloride was increased. Stress corrosion cracking began appearing on the specimens at concentrations of 400 ppm of sodium chloride. Cracks at this concentration were few in number but well defined as shown in Figure III. As the concentration of sodium chloride was increased the number of cracks increased in number but became very small and hard to differentiate from corrosion pitting. Figure IV shows a specimen that was processed using rinse water containing 1600 ppm of sodium chloride.

The quantity of sodium chloride which was deposited on the surface of the specimens prior to stress relieving was determined by a radioisotope technique.

The results of these tests are listed in Tables I and II.

TABLE I

THE EFFECTS OF SODIUM CHLORIDE IN RINSE WATER SOLUTIONS

SET	COMPOSITION OF RINSE WATER SOLUTIONS	EFFECTS OBSERVED DURING PROCESSING	
		TITANIUM FROM TITANIUM METALS COMPANY	TITANIUM FROM REM CRU CORPORATION
A	Distilled Water		Smooth, even surface. No evidence of pitting or cracking.
B	Distilled Water Containing 400 ppm of Sodium Chloride		Small areas of pitting. Average of two cracks per panel. Cracks relatively large and well defined.
C	Distilled water containing 1600 ppm of Sodium Chloride		Increased pitting and selective etching. Evidence of a large number of small stress corrosion cracks which were difficult to differentiate from corrosion pitting.
D	Distilled water containing 3200 ppm of Sodium Chloride		Large pitted areas covering approximately 50% of the specimen surface area. Selective etching very evident, with cracking comparable to that observed at 1600 ppm.
E	Distilled water	Smooth, even surface. No evidence of corrosion pitting or cracking	
F	Distilled water containing 1600 ppm of Sodium Chloride	Corrosion pitting evident over large areas of the surface. Numerous stress corrosion cracks which were difficult to differentiate from corrosion pitting.	
G	Distilled water containing 3200 ppm of Sodium Chloride	Approximately 50% of surface area covered with corrosion pitting. Stress corrosion cracking comparable with specimens rinsed in water containing 1600 ppm of sodium chloride.	

TABLE I (CONTINUED)

THE EFFECTS OF SODIUM CHLORIDE IN RINSE WATER SOLUTIONS

EFFECTS OBSERVED DURING PROCESSING

SET	COMPOSITION OF RINSE WATER SOLUTIONS	TITANIUM FROM TITANIUM METALS COMPANY	TITANIUM FROM REM CRU CORPORATION
H	Distilled water containing 9600 ppm of Sodium Chloride	Approximately 75% of surface area covered with corrosion pitting. Stress corrosion cracking comparable with specimens rinsed in water containing 1600 and 3200 ppm or Sodium Chloride	

TABLE II

AVERAGE APPARENT ADSORPTION OF SODIUM CHLORIDE ON THE TITANIUM SURFACE

SANPLE NO.	SODIUM CHLORIDE IN DISTILLED WATER RINSE SOL. (PPM)	STANDARD SOLUTION	BACKGROUND (CPM)	TOTAL ACTIVITY (CPM)	CORRECTED ACTIVITY (CPM)	AMOUNT OF SODIUM CHLORIDE ADSORBED (gms)	AVERAGE APPARENT ADSORPTION OF SODIUM CHLORIDE PER UNIT AREA OF MATERIAL (gms/in^2)
1	400	I	120	140.2	20.2	2.08×10^{-5}	4.33×10^{-6}
2	400	I	120	140.2	20.2	2.08×10^{-5}	
3	1600	I	120	142.1	22.1	9.36×10^{-5}	2.65×10^{-5}
4	1600	I	120	148.0	28.0	1.18×10^{-4}	
5	1600	II	125	198.5	74.0	1.36×10^{-4}	
6	1600	II	125	214.2	89.0	1.62×10^{-4}	
7	3200	II	125	200.4	75.0	2.75×10^{-4}	5.78×10^{-5}
8	3200	II	125	202.7	77.0	2.82×10^{-4}	
9	6400	II	125	211.0	86.0	6.29×10^{-4}	1.15×10^{-4}
10	6400	II	125	190.0	65.0	4.77×10^{-4}	
11	9600	II	125	217.0	92.0	1.01×10^{-3}	1.73×10^{-4}
12	9600	II	125	185.0	60.0	6.60×10^{-4}	

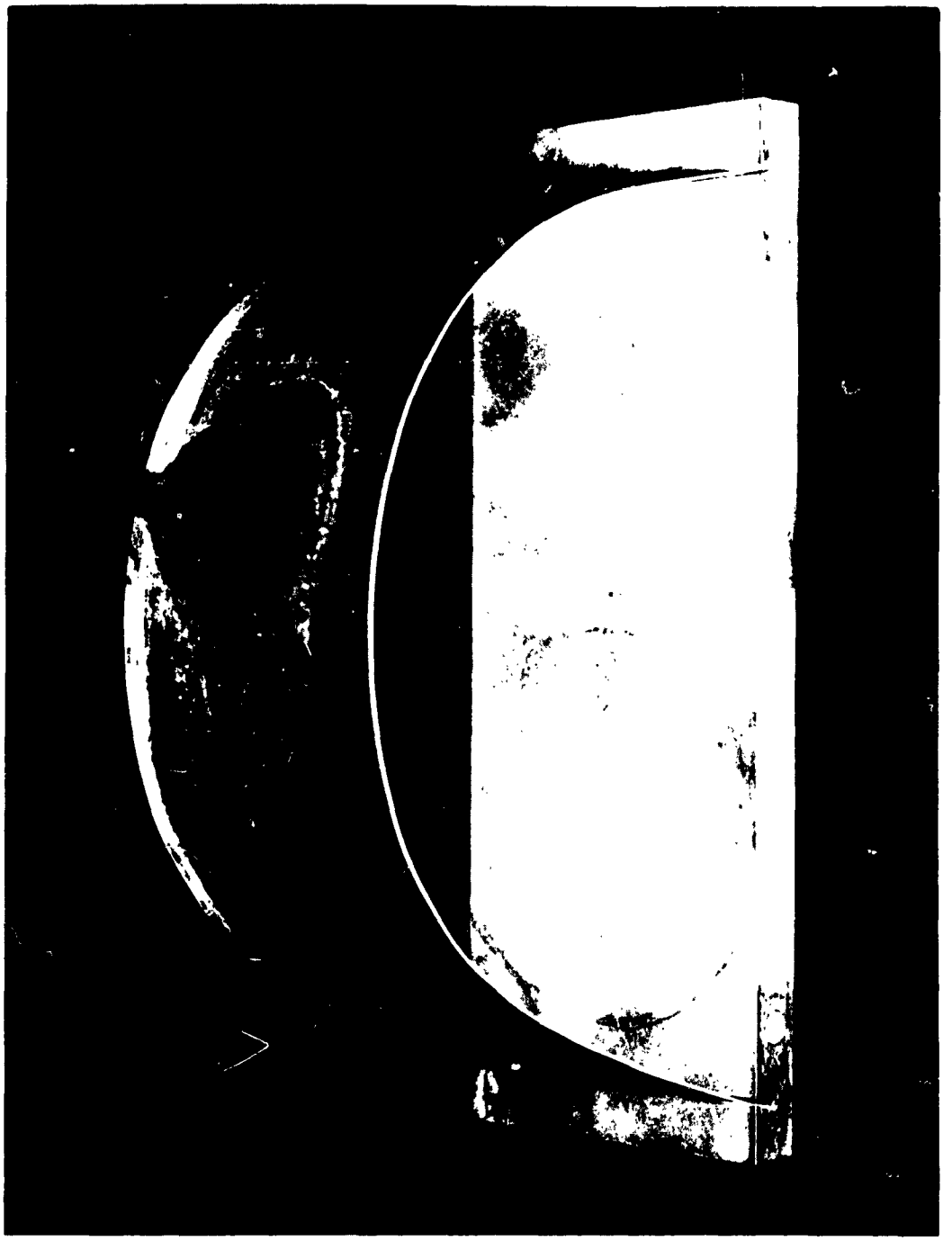

FIGURE I

SPECIMEN UNDER STRESS

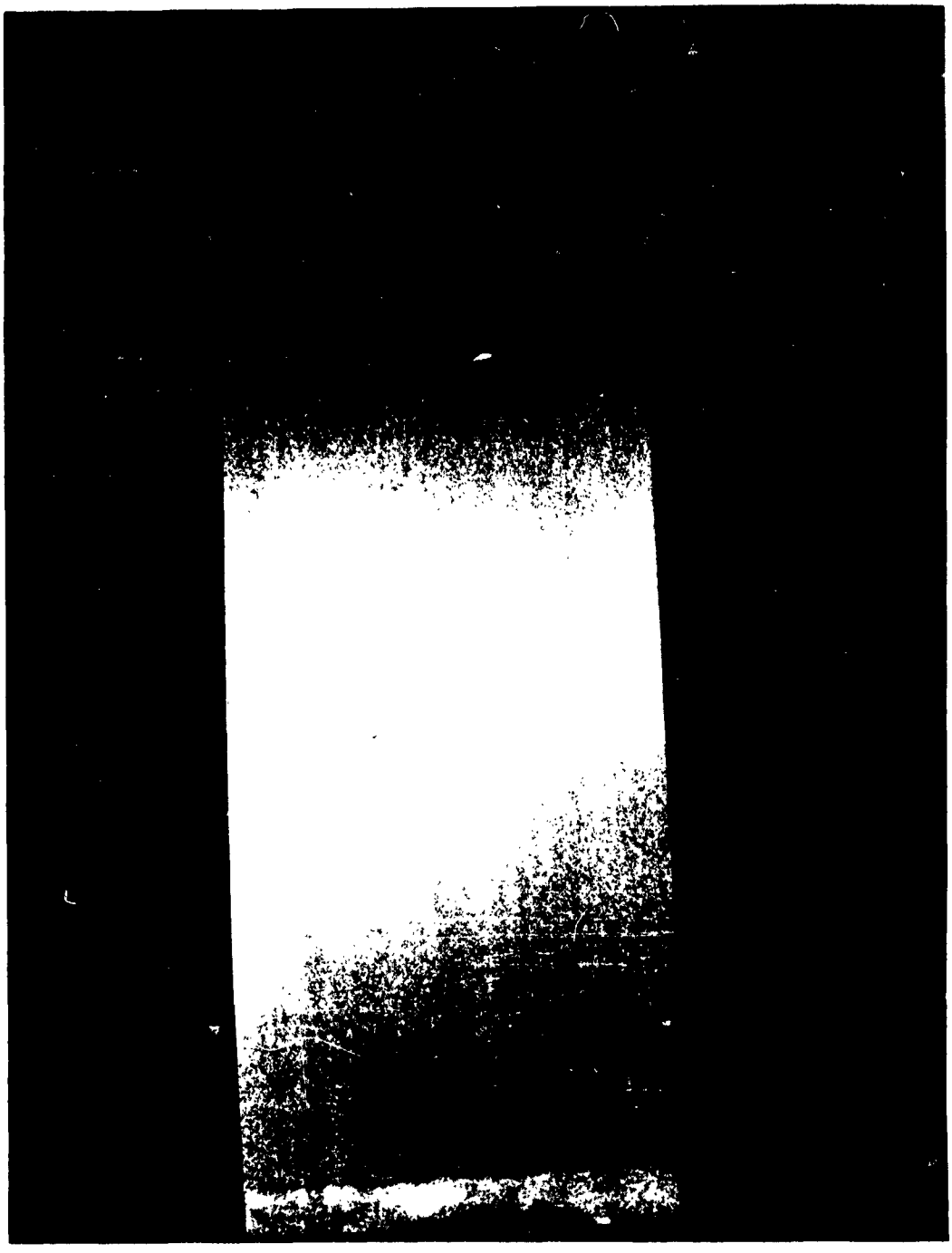

FIGURE II

SPECIMEN PROCESSED USING PURE DISTILLED WATER AS THE RINSE SOLUTION

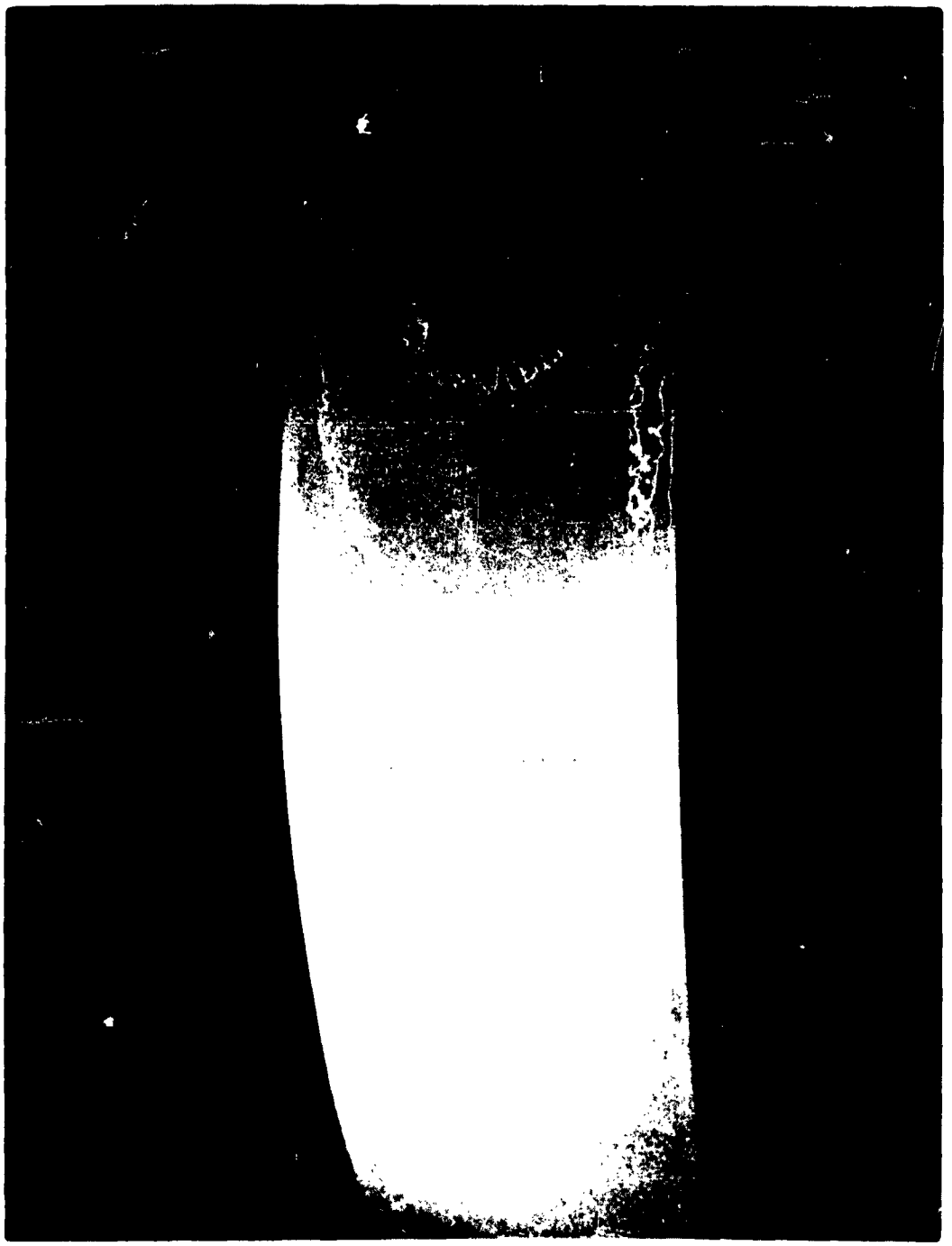

FIGURE III

SPECIMEN PROCESSED USING 400 PPM OF SODIUM CHLORIDE IN DISTILLED WATER FOR THE RINSE SOLUTION

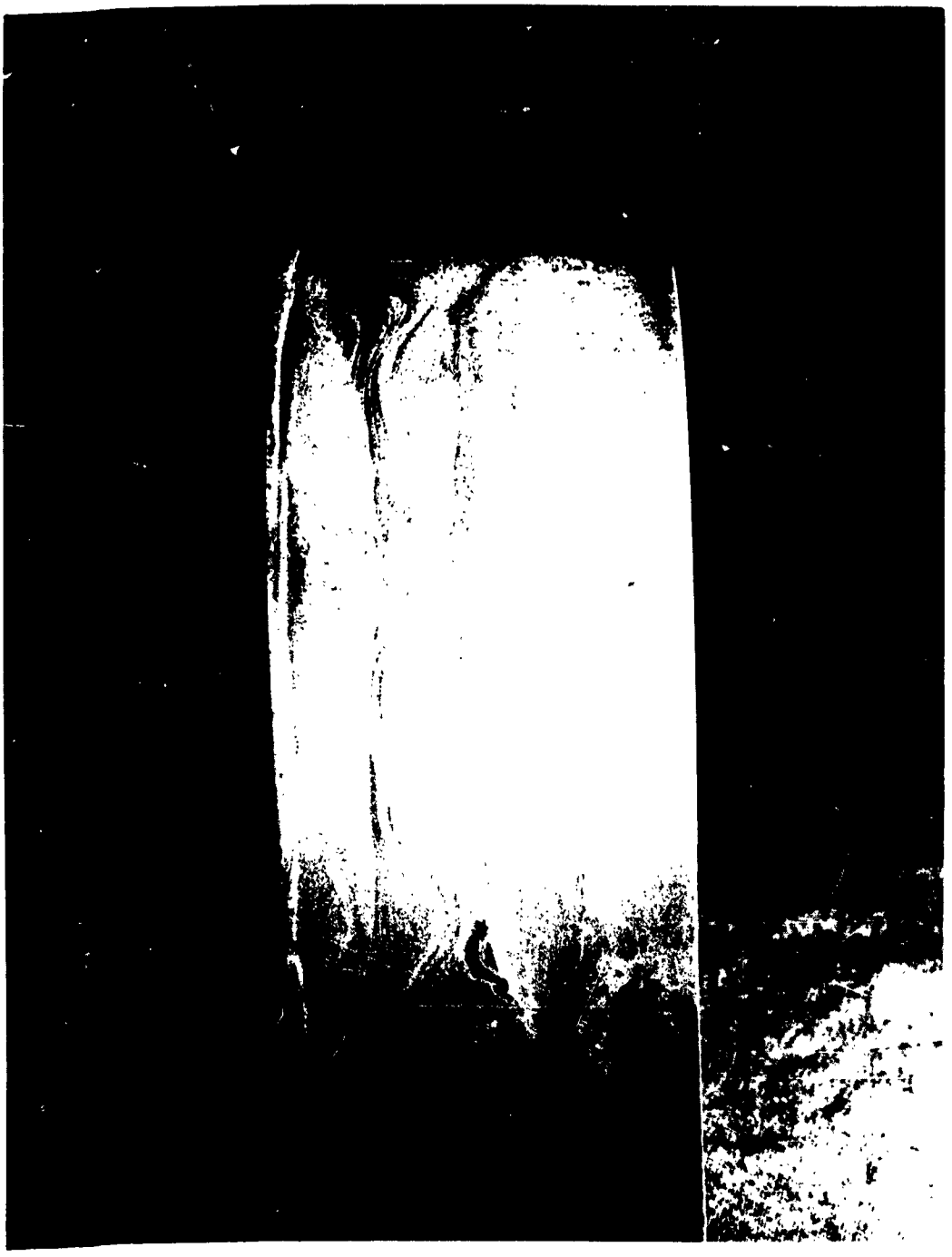

FIGURE IV

SPECIMEN PROCESSED USING 1600 PPM OF SODIUM CHLORIDE IN DISTILLED WATER AS THE RINSE SOLUTION

NOTE: The test data from which this report was prepared are recorded in Materials and Processes Test Laboratories Data Book No. 898.